Water Ponding on Level Basins Caused by Precipitation

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ABSTRACT

LEVEL basins, areas of any configuration with no slope and surrounded by a control dike, provide a unique land shape within which water from both irrigation and precipitation can be uniformly distributed on cropped fields and within or from which no erosion will occur. Excess water retained on level basins, however, can interfere with crop production.

The hydrology component of the CREAMS model was modified to estimate ponding (inundation) events on level basins for any region with or without irrigation. Ponding was assessed by looking at the duration of inundation events (ponding time) on a monthly basis for various return periods.

Differing precipitation amounts and patterns were studied by using weather data from three climatically different regions represented by Phoenix, AZ; North Platte, NE; and Columbia, MO. As monthly rainfall increased, expected ponding time also increased. For the "worst case" situation studied (Columbia in June), the ponding time would exceed 10 h every 10 years only when the final infiltration rate was less than about 2.5 mm/h. As final infiltration rates increased beyond 2.5 mm/h, the expected ponding times decreased rapidly to durations of less than 5 h. Irrigating tended to increase the ponding time expected from rainfall events (due to the likelihood of rainfall following an irrigation).

INTRODUCTION

Agriculture needs to more efficiently utilize irrigation and precipitation for crop production. Nonuniformity of infiltrated water is typically caused by areal redistribution of surface water from rainfall (runoff form higher- to lower-lying areas within the field) or runoff from field (lost to that field). Improved conjunctive use of precipitation and irrigation can be attained by preventing runoff from irrigation and precipitation. Irrigation requirements can be reduced by more fully utilizing natural precipitation.

Level basins (Erie and Dedrick, 1979; and Dedrick et al., 1982), areas of any configuration with no slope and surrounded by a control dike, provide an unique land shape within which water from precipitation and/or irrigation can be uniformly distributed and runoff can be eliminated. Irrigated level basins are being used mainly in arid to semiarid regions. Advantages of level basins include (a) water is applied uniformly without causing runoff or erosion and (b) the need for irrigation can be reduced or eliminated by effectively using the water received from precipitation. Level-basin use is limited by (a) the need for precise land leveling (generally laser-controlled), (b) topography (level basins limited to relatively level land), (c) soil-infiltration, both rate and spatial variability, and (d) areas of shallow top soil. Excessive water on level basins, either from precipitation or irrigation or both, can adversely affect crop (e.g., crop damage and yield reduction, or trafficability problems associated with normal field operations).

Whether a crop will be damaged by excess water, i.e., long inundation on a level basin, depends mainly on the crop (Bourget et al., 1966); the growth stage of the crop (Howell and Hiler, 1974; Chaudhary et al., 1975; Howell, et al., 1976; Singh and Ghildyal, 1980); the duration and frequency of flooding (Chaudhary et al., 1975; Singh and Ghildyal, 1980; Zolezzi et al., 1978); and the soil and atmospheric temperatures (Bowen et al., 1971; Fausey and McDonald, 1985). Hence, there is a need to evaluate the extent that precipitation, either alone or in conjunction with irrigation, may cause ponding on level basins.

Predicting excess or ponded water on a level basin is the topic of this paper. The objectives were to develop a procedure to predict inundation or ponding events on level basins and to assess how precipitation or a combination of precipitation and irrigation affects ponding events. Ponding event statistics were developed for three climatologically differing regions represented by Phoenix, AZ (annual precipitation 179 mm, growing season precipitation 82 mm, and sunshine 86% of possible [Visher, 1966]), North Platte, NE (445 mm, 301 mm, and 65%) and Columbia, MO (939 mm, 512 mm, and 63%). Statistics from each region illustrate the effects that differing precipitation amounts and patterns can have on the use of level basins. Required surface drainage during excess water periods, topography and associated leveling costs, and the economic aspects of adapting level basins are all recognized as important factors when considering level basins, but were not part of this study.

METHOD OF ANALYSIS

A computer simulation model was used to gain a general understanding of the effects that precipitation

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can have on the use of level basins in different rainfall regions. Such an approach has the advantage of quick assessment without years of field study. The accuracy of the model projections may be questioned, however, if not field verified. This limitation is commonly recognized in modeling any real-world phenomenon. Several key factors within the model were verified for their predictive capability.

Precipitation will essentially remain where it falls on level basins and must ultimately infiltrate or evaporate. Whether or not ponding of water will occur depends on the infiltration rate of the soil and the rate at which water is added. Soil water is replenished by infiltrated water and depleted continuously between precipitation events by evapotranspiration and deep percolation. In equation form this can be written as

$$SM_i = SM_{i-1} + F_i - ET_i - O_i \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

for a daily time interval where i is day of analysis, SM is soil water storage, F is infiltration, ET is evapotranspiration, and O is deep percolation.

The hydrologic component of the mathematical model CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems [Knisel, 1980]) was used as a basis to simulate the water balance in the soil profile on a continuous basis. The hydrologic component estimates the water balance elements from rainfall events. Items estimated include infiltration and runoff, evapotranspiration for a particular crop, and percolation.

Two major modifications were made in the CREAMS model so that ponding or inundation events on level basins could be estimated. These included (a) addition of an algorithm to estimate ponded water from rainfall and (b) provisions for adding irrigation water to a basin based on soil water depletion, which would then become part of the hydrologic cycle of the level basin.

Estimating Ponded Water

In the CREAMS model, the amount of water that infiltrates is the precipitation minus runoff. All rainfall on a level basin, however, stays within the basin boundaries and eventually infiltrates. The time to infiltrate ponded water was paramount to this study and required that the amount of water ponded on a level basin from a rainfall event be known. Two options are available in the CREAMS model to estimate runoff from precipitation. If only daily rainfall records are available, the Soil Conservation Service (SCS) curve number technique (USDA, 1972) is used. If storm rainfall data are available, breakpoint or hourly rainfall and the Green-Ampt infiltration equation are used. The SCS curve number technique was selected since the required inputs are generally available for many locations.

The curve number technique was used to separate the water added by rainfall and/or irrigation into "at once" infiltration and runoff. The runoff was used as an estimate of the ponding depth on the basin. This ponded depth of water was then infiltrated at the final (saturated, steady-state) infiltration rate of the soil. The infiltration time for the ponded water was then used as an estimate of inundation time (ponding time). Evapotranspiration is computed by a method developed by Ritchie (1972), which is based on the Penman equation with climatic inputs of solar radiation and air temperature. Flow through the root zone is predicted with a soil storage routing technique developed by Williams and Hann (1978).

The amount of water infiltrated on any day in equation [1] can be supplied by precipitation and/or irrigation and/or noninfiltrated water from the previous day. It was assumed that every irrigation event causes some ponding on the basin. When a precipitation event occurs on the same day as an irrigation, all water from precipitation was infiltrated at the final infilitration rate (no precipitation absorbed "at once"). Total time of ponding for the described event was found by adding ponding durations from the irrigation and precipitation events.

Several assumptions for the simulation of the inundation process on level basins were made. The soil is considered to be uniform, with uniform hydraulic conductivity and without impeding layers; the water table is far below the surface so that there is no capillary rise; and all seepage below the root zone (percolation) is lost to the system. Precipitation and irrigation on the soil may act to compact and seal the surface affecting infiltration, and thus the inundation process; but these factors were not taken into account.

Irrigation

The original hydrologic section of the CREAMS model was modified so that water could be added to the hydrologic process through an irrigation event. An updated version (version 1.8) of the CREAMS model now includes an irrigation option (Personal Communication, Knisel, 1985).

Two general irrigation strategies are possible: (a) a fixed amount of water to be added when the soil water content in the root zone is depleted to a specified level and (b) a variable amount of water to be added at fixed intervals. The first strategy is the most representative of surface irrigating and was used in the model development. The strategy depends on a schedule describing when to irrigate (timing) and how much water to apply (quantity). The soil water depletion level was used to key the model to apply an irrigation. The model allowed irrigation at either 45%, 55%, or 65% depletion of available soil water. The quantity of water applied was based on refilling the root zone to field capacity or to 75% of field capacity (deficit irrigation). An option of no irrigation (dryland agriculture) was included. The irrigation strategies considered, along with the amount of water required per irrigation for each strategy and three soils, are shown in Table 1. Irrigation strategies that result in irrigation amounts smaller than minimum

TABLE 1. IRRIGATION STRATEGIES AND RESULTING IRRIGATION AMOUNTS FOR EACH SOIL TYPE

Irrigation strategy	Depletion of available soil water	Replenishment level as % of field capacity	Irrigation amount: Loamy sand	Loam	Silty clay
	%		mm/m		
1	65	100	54	108	130
2	55	100	46	91	110
3	45	100	38	74	90
4	65	75	33	67	80
5	55	75	25	50	60
6	No irrigation			No irrigation	

amounts that can be applied in practice to level basins should be avoided. No adjustments were made for this limitation in this study.

Other

The CREAMS model was modified to use weather data input generated by using the Richardson and Wright (1984) computer simulation model WGEN (Weather GENerator) rather than a series of actual daily values. The data generated included daily rainfall, maximum and minimum temperatures, and solar radiation. The advantages of a generated weather data series are that a long, e.g., 50-year, complete series can be easily obtained in the required format.

Soil and crop characteristic files were added. Required soils data were final infiltration rates, available soil water, and curve numbers. Specific information on the soil characteristics and estimates of the curve number should be used for a test site, if available, and can be easily entered into the program.

Initialization paramters of crop planting date and date of last seasonal irrigation were added. The crop grown at Phoenix was cotton, while corn was grown at the other locations. The planting date and date of last seasonal irrigation were April 1 and September 27, May 1 and August 28, and April 25 and August 23 for Phoenix, North Platte, and Columbia, respectively. The same crop was used for the entire 50-year simulation period. The rooting depth used for cotton and corn was 1.0 m, which accounts for 80% to 90% of soil water extracted by the roots (Doorenbos and Kassam, 1979; Erie et al., 1982). Locally recommended planting dates were used. The date of last irrigation was chosen to be 25 to 30 days before harvest.

The leaf area index (LAI) is used in the CREAMS model to characterize the crop seasonal development. A LAI greater than zero is used to key when evapotranspiration starts. When the soil water content falls below the predetermined depletion level, an irrigation is given the next day. The model simulates a preseason irrigation if 25% of the available soil water in the soil profile is depleted 7 days before planting.

Various watershed characteristics such as drainage area, main-stem channel slope, and length-width ratio of the watershed were deleted from CREAMS since no runoff occurs. This modified version of the CREAMS model is referred to as LEVBA (LEVel BAsin). Details of the LEVBA model are found in Reinink (1985).

MODEL VERIFICATION

CREAMS/LEVBA Model

The SCS curve number technique was used in this study since required inputs (daily rainfall) can be easily obtained for many locations. The hydrology component of the CREAMS model based on the SCS curve number technique has been tested on a number of watersheds in the United States. Knisel (1980) reported that the model generally approximated long-term water yield well. Individual runoff events and monthly totals were not always highly correlated but standard deviations of predicted and measured runoff were similar.

Knisel also states that "average evapotranspiration and percolation predictions seem realistic. Limited data prohibited percolation and evapotranspiration model tests as extensive as those of the runoff model." The

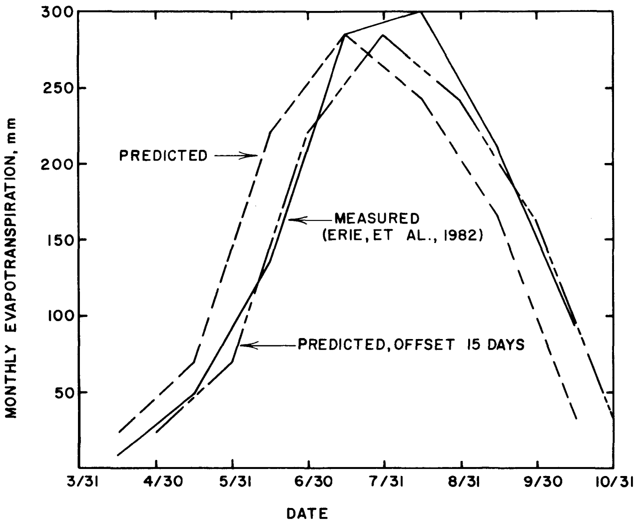

Fig. 1—Mean evapotranspiration for cotton measured at Mesa and Tempe, AZ compared to that predicted for Phoenix, AZ using LEVBA, the modified version of the CREAMS model. Measured values are a mean of nine seasons while the simulated results are an average of a 10-year sequence selected at random for the 50-year simulation study. Mesa and Tempe are in the immediate vicinity of Phoenix.

evapotranspiration predicted for cotton grown near Phoenix was compared to those measured by Erie et al. (1982), Fig. 1. The measured values are a mean of nine cotton crops grown at Mesa and Tempe, AZ in the 1950s and early 1960s. The simulated results are an average for a 10-year sequence, selected at random, from the 50-year simulated study. The simulated evapotranspiration for the growing season was about 4% less than that measured (1040 mm vs. 1080 mm), but is offset in time by about 15 days (simulated leads measured). This time offset can partially be explained by differences in planting date. April 1 was used as the planting date for the simulation study, while actual planting dates for the Erie et al. (1982) results varied from April 1 to April 15 depending on the year. The predicted peak monthly values, offset by 15 days, compare remarkably well to those measured.

Irrigations for the cotton in Phoenix were typically applied when 65% of the available water had been depleted. Number of irrigations per year ranged from 5 to 7, averaging 6.3 for the 9 years (Erie et al., 1982). The simulation study yielded 6.8 irrigations per year for an irrigation strategy and soil type similar to that used by Erie. The volume of water added by the simulation model was the exact amount needed by the crop (uniformity and efficiency assumed to be 100%). The irrigation uniformity for the cotton studies was high, hence the number of irrigations applied are comparable.

Weather Generator (WGEN) model

Generated and observed monthly values of the number of wet days, rainfall, maximum and minimum air temperatures, and solar radiation for Phoenix, North Platte, and Columbia are shown in Table 2. Observed and generated values for rainfall and solar radiation were not significantly different either on a monthly or annual basis. Some significant differences between actual and generated monthly maximum and minimum temperatures occurred but generally compared well. Also, the mean number of wet days on a monthly basis was accurately simulated at all three locations.

TABLE 2. GENERATED AND OBSERVED MONTHLY VALUES OF NUMBER OF WET DAYS, RAINFALL, AVERAGE MAXIMUM AND MINIMUM TEMPERATURES AND SOLAR RADIATION.

Month	Wet Days (Precipitation >0.25 mm)		Precipitation		Temperature Max		Temperature Min		Radiation	
	Obs	Gen	Obs	Gen	Obs	Gen	Obs	Gen	Obs	Gen
Phoenix*	Number		–mm–		–°C–		–°C–		–Ly–	
Jan	4	4	18	21	17.8	17.8	1.8	1.7	300	294
Feb	4	3	15	13	20.1	20.4	3.8	3.9	405	365
Mar	3	4	19	26	23.9	23.6	6.1	5.8	524	455
Apr	2	2	8	10	28.8	28.7	10.2	10.2	631	572
May	1	1	4	5	33.8	33.3	13.9	13.2	709	663
Jun	1	1	3	6	38.7	38.3	18.6	18.1	721	692
Jul	4	3	19	17	40.3	40.3	23.9	23.6	648	669
Aug	5	5	31	35	38.7	38.4	23.0	22.6	599	595
Sep	3	3	17	24	36.8	36.4	19.6	19.3	546	493
Oct	2	2	12	18	30.4	30.2	12.6	12.2	441	397
Nov	3	2	12	14	23.2	22.9	5.8	5.6	330	308
Dec	4	4	21	26	18.9	18.8	2.8	2.8	274	265
Total or Average	36	34	179	215	29.3	29.1	11.8	11.6	511	481
North Platte†										
Jan	6	5	10	11	2.7	0.1	–11.6	–11.4		196
Feb	5	5	9	16	5.3	5.8	–9.0	–8.8		271
Mar	6	6	23	20	9.7	10.0	–4.8	–4.8		385
Apr	8	7	52	44	16.6	16.3	1.9	1.7		496
May	9	9	68	72	22.1	22.4	7.8	7.9		579
Jun	9	9	74	99	27.5	27.7	13.3	15.1		616
Jul	8	9	61	69	31.9	31.9	16.8	16.9		602
Aug	9	7	54	45	30.8	30.7	15.4	15.5		520
Sep	4	6	44	50	25.7	25.6	9.6	9.5		415
Oct	5	4	26	20	19.4	18.7	2.5	1.7		309
Nov	6	4	14	12	10.3	10.7	–4.9	–4.6		219
Dec	4	4	10	10	4.2	4.6	–9.5	–9.2		179
Total or Average	79	75	445	468	17.2	17.0	2.3	2.5		399
Columbia‡										
Jan	8	7	43	38	4.1	4.4	–5.9	–5.6	184	187
Feb	8	8	46	48	6.2	7.0	–4.3	–3.8	260	254
Mar	11	9	67	61	11.1	10.6	–0.1	–0.9	338	353
Apr	11	10	84	87	18.4	18.7	6.6	6.7	431	459
May	11	10	119	109	23.8	24.1	12.2	12.4	482	557
Jun	11	10	110	108	29.1	29.1	17.6	17.7	570	587
Jul	9	8	87	97	32.1	32.2	19.8	19.8	565	579
Aug	8	6	97	64	31.2	31.1	19.0	18.9	521	516
Sep	8	6	99	80	27.1	27.5	14.3	14.5	429	403
Oct	7	7	79	79	21.1	20.9	8.5	8.2	322	288
Nov	7	6	58	39	11.8	11.9	0.7	0.7	212	211
Dec	8	7	50	45	5.8	5.7	–3.8	–4.1	166	167
Total or Average	107	96	939	855	18.5	18.6	7.1	7.0	373	380

*Phoenix, AZ. Weather station located at Phoenix, Sky Harbor; Latitude: 33° 26'N; Longitude: 112° 0.1'W; Elevation (ground): 340 m.
†North Platte, NB. Weather station located at North Platte, Lee Bird Field; Latitude: 41° 08'N; Longitude: 100° 41'W; Elevation (ground): 847 m.
‡Columbia, MO. Weather station located at Columbia, Municipal Airport; Latitude: 38° 58'N; Longitude: 92° 22'W; Elevation (ground): 237 m.

TABLE 3. FREQUENCY DISTRIBUTION OF PONDING EVENTS FROM RAINFALL ON A SILTY CLAY SOIL AT NORTH PLATTE, NEBRASKA FOR AN IRRIGATION STRATEGY OF 65% DEPLETION AND FILLING ROOT ZONE TO FIELD CAPACITY. THE LONGEST PONDING PERIOD FOR THE 50-YEAR SIMULATION WAS 43 h

Month	Duration class, hours											
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total
	Number of events in 50 years											
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	2	1	0	1	0	0	0	0	0	0	0	4
Mar	5	1	0	0	0	0	0	0	0	0	0	6
Apr	30	6	12	1	3	2	2	2	0	1	4	61
May	43	18	10	13	4	4	3	3	2	1	7	108
Jun	44	23	15	12	7	8	1	5	1	4	16	136
Jul	26	6	4	4	3	2	3	3	1	1	5	58
Aug	24	13	10	1	4	3	1	0	2	0	10	68
Sep	16	9	91	1	1	1	1	3	1	0	4	46
Oct	2	0	1	0	0	1	0	0	0	0	0	4
Nov	2	0	0	0	0	0	0	0	0	0	0	2
Dec	0	0	0	0	0	0	0	0	0	0	0	0
Total	194	77	61	33	22	21	11	14	7	7	46	493

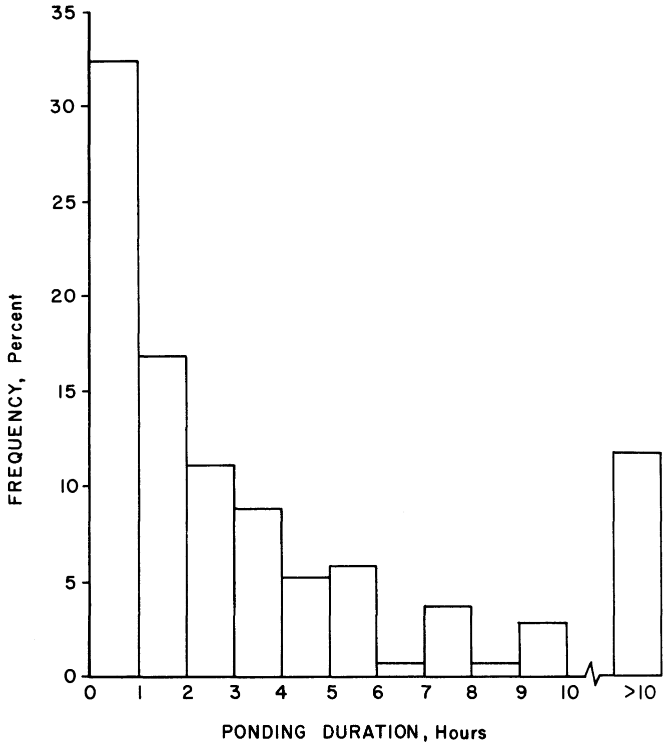

Fig. 2—Frequency distribution of ponding events from rainfall for the month of June at North Platte, NE. Corn is being grown on silty clay soil. An irrigation was applied, whenever 65% of the available soil water was depleted. The root zone was refilled to field capacity. The duration classes are shown as a percent of the 136 ponding events that occurred during June over the 50-year study, see Table 3.

DATA ANALYSIS

Frequency analyses were used to estimate the duration of an inundation event that can be expected for a given return period. Return period was defined as the average elapsed time between occurrences of an event of a certain magnitude. Frequency analyses procedures described by Haan (1977) were used. Events were considered on a monthly basis with a frequency interval of one hour. Frequency distributions of inundation duration were developed for a location for each irrigation strategy by soil type. Data for a silty clay soil at North Platte and an irrigation strategy of refilling the root zone to field capacity when 65% of the available soil water was depleted are shown in Table 3. These data represent the number of inundation events from rainfall in 50 years. Data for the month of June are shown as a frequency histogram in Fig. 2. The frequency histogram is an approximation of the probability distribution.

Maximum ponding duration for 1-, 2-, 5- and 10-year return periods were developed for each soil on a monthly basis. An example of these statistics is illustrated graphically in Fig. 3, where ponding duration (ponding time) is shown as a function of return period. Coefficients of determination (R^2) from the "best fit" curves using a logarithmic regression analysis were generally 0.95 or higher. The best fit lines, as possible indicators of ponding duration for longer return periods, were extrapolated to 50 years (dashed lines), but should be used with caution.

RESULTS AND DISCUSSION

Level basins have been used successfully for many years in the arid to semiarid regions of the United States

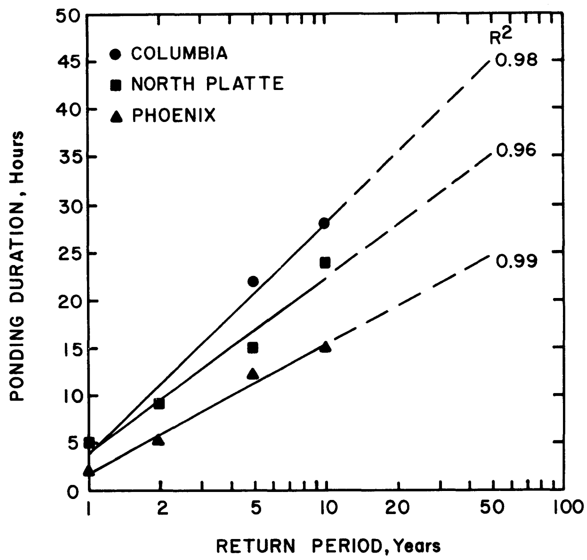

Fig. 3—Ponding duration related to return period for the month with the longest ponding durations for each location studied. The soil was silty clay. Irrigations were applied to refill the root zone to field capacity whenever 65% of the available soil water was depleted. Observed mean monthly rainfall amounts are 110 mm for June at Columbia, 74 mm for June at North Platte and 31 mm for August at Phoenix.

(Dedrick et al., 1982). To gain an insight into how level basins might perform in regions with more precipitation, especially during the growing season, ponding event statistics were developed for climatological regions represented by Columbia (humid) and North Platte (semiarid). For comparative purposes ponding statistics for level basins were generated for an arid zone represented climatologically by Phoenix.

Effects of More Rainfall

The expected ponding duration for various return periods for the three locations provides some insight into the effects of increased rainfall amounts, Fig. 3. These data are for the month with the longest ponding durations for each location on the lowest infiltration rate soil (silty clay, 1.3 mm/h). As expected, the ponding time increased as monthly rainfall increased, ranging from about 15 h at Phoenix to about 28 h at Columbia for a 10-year return period.

Ponding durations plotted against return periods for all months during the growing season and for all three

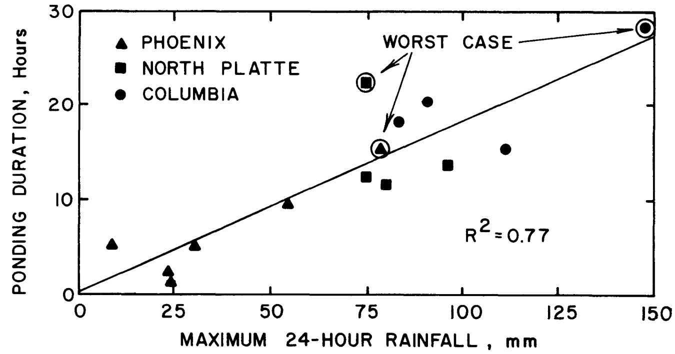

Fig. 4—Ponding duration expected every ten years related to the maximum 24-h rainfall on record for a particular month. Data are for the three climatologically different locations studied. The soil was silty clay, and irrigations were applied when 65% of the available water was depleted. The root zone was refilled to field capacity.

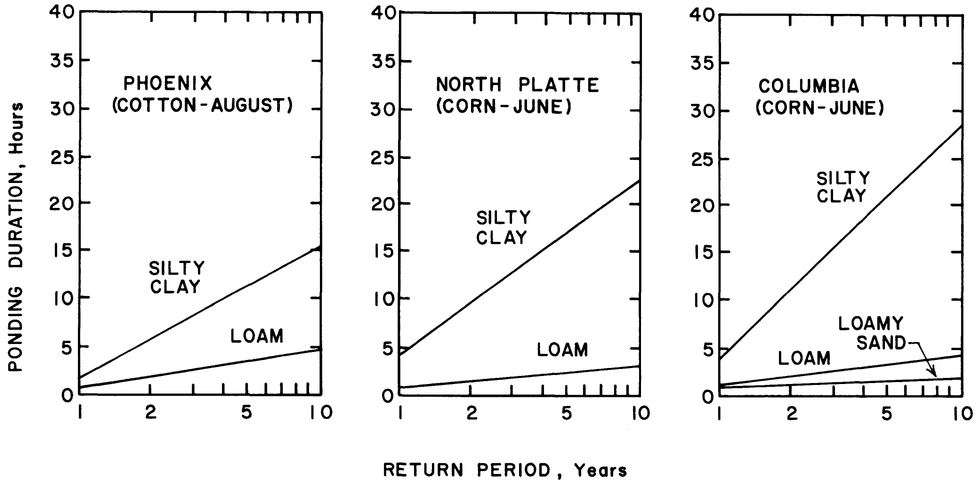

Fig. 5—Ponding duration related to return period for the soil types studied at each location. Ponding on loamy sand never exceeded 1 h at Phoenix and North Platte. Irrigations were applied to refill the root zone to field capacity whenever 65% of the available soil water was depleted.

locations were used to relate ponding duration to maximum 24-h rainfall (U.S. Department of Commerce, 1952), Fig. 4. The maximum 24-h rainfall used in the figure was the maximum on record for a particular month. A fairly good relation exists ($R^2 = 0.77$ for linear best fit) for the conditions presented: return period of 10 years, low infiltration rate soil, and with irrigations being applied when 65% of the available water had been depleted and the soil was refilled to field capacity. The "worst case" points shown represent the months with the longest ponding durations for each location illustrated in Fig. 3. Interestingly, two of the three extremes fall essentially on the best fit line, while the June data from North Platte deviates the most. Ponding duration increased 1.8 h for every 10 mm increase in the maximum 24-h rainfall. Hence, the maximum expected ponding duration would be about 10 h every 10 years if the maximum 24-h rainfall were 55 mm. Twenty-four hour ponding could be expected if the maximum monthly 24-h rainfall were about 135 mm, Fig. 4.

Effects of Soil Texture (Infiltration)

The return period and ponding duration plots for the month with the longest ponding durations were used to also illustrate the effects of soil texture on potential ponding, Fig. 5. Final infiltration rates were 10.2 mm/h, 3.8 mm/h, and 1.3 mm/h for the loamy sand, loam, and silty clay soils, respectively. The most significant point is that soils with final infiltration rates of 3.8 mm/h or greater have very short ponding duration (< 5 h for a 10-year return period). This was the case for all three climatic regions. In Phoenix and North Platte, ponding durations on loamy sand never exceeded one hour for any month or irrigation strategy evaluated and consequently are not shown in Fig. 5. At Columbia, ponding on loamy sand would only be about 1.5 h every 10 years.

Ponding durations for a 10-year return period were plotted against final infiltration rates for Columbia and North Platte, Fig. 6. Both data sets were for June. On a soil with a final infiltration rate of about 2.5 mm/h or more, the ponding duration expected every 10 years would be 10 h or less at both Columbia and North Platte. Further, the ponding durations would be considerably less than 5 h at both locations when the final infiltration rate was 4 mm/h or more.

Effects of Irrigation

Analyses were completed for various irrigation strategies as well as for dryland agricultural conditions. The crop must be irrigated at Phoenix, hence results from no irrigation were not applicable.

Ponding durations expected for a 10-year return period for level basins on silty clay are shown on a monthly basis in Table 4. No irrigations were applied during May and June at Columbia (ponding duration was the same for all irrigation and the nonirrigation strategies). Irrigation had the most notable effect on ponding time at Columbia during August, but inundation times were not as long as those expected in June. Irrigation influenced the ponding time for all months at North Platte, being most apparent during July

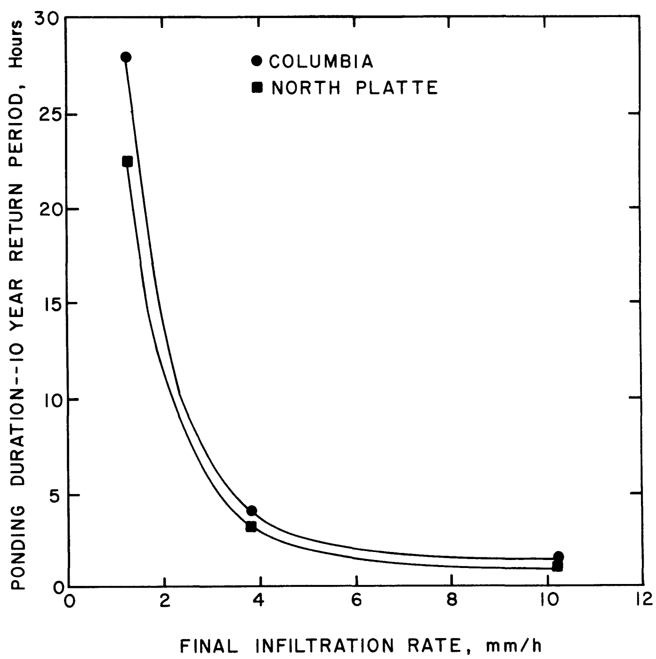

Fig. 6—Ponding duration for a 10-year return period related to final infiltration rate of the soil. Data are for the month with the longest ponding durations (June). Occasional irrigations were applied at North Platte whenever 65% of the available soil water was depleted. The root zone was refilled to field capacity. No irrigations were applied at Columbia during June.

TABLE 4. EXPECTED PONDING DURATION FROM RAINFALL FOR A 10-YEAR RETURN PERIOD ON SILTY CLAY FOR FIVE IRRIGATION STRATEGIES EVALUATED AT PHOENIX, AZ; NORTH PLATTE, NE; AND COLUMBIA, MO

	Irrigation strategy					
	1	2	3	4	5	6
Depletion level, percent of available soil water	65	55	45	65	55	No irrigation
Replenishment level, percent of field capacity	100	100	100	75	75	
	Hours					
Phoenix						
Apr	2	2	2	2	2	
May	1	1	1	1	1	
Jun	7	3	4	2	2	
Jul	5	5	8	5	7	
Aug	15	13	13	9	10	
Sep	9	9	9	7	8	
North Platte						
May	13	13	13	13	13	10
Jun	24	24	23	24	24	18
Jul	12	12	12	10	10	5
Aug	13	10	9	8	10	2
Sep	9	7	10	7	8	6
Columbia						
May	20	20	20	20	20	20
Jun	28	28	28	28	28	28
Jul	18	16	18	14	16	14
Aug	16	23	17	16	18	8
Sep	13	13	15	15	13	12

and August. Similar to Columbia, ponding times during August were shorter than those expected in June.

Irrigation strategy at Columbia had little influence on ponding duration, i.e., the ponding duration from a 65% depletion and 100% refill irrigation strategy was about the same as from a strategy of 65% depletion and 75% refill. In contrast, the irrigation strategy at Phoenix or North Platte affected the expected ponding times, especially if the root zone was not completely refilled. Such an effect was expected. Whether or not such a strategy could be attained on a level-basin system may, however, be questionable and would be of no benefit in an arid climatic region.

Aside from the potential problem of ponding caused by rainfall, long ponding periods are associated with the irrigation event itself when on low infiltration rate soils. The ponding time is directly related to the quantity of water applied per irrigation, hence the lighter applications associated with irrigation strategies 2 through 5 tend to alleviate the problem. Ponding times from irrigation only were not excessive on either loam or loamy sand soils, e.g., ponding times were less than 6 h.

SUMMARY AND CONCLUSIONS

The CREAMS model was modified to convert would-be-runoff on unleveled land to ponded water on a level basin. The model was also changed so that water could be added to the system artificially (irrigation) according to a predetermined scheme or schedule. The model LEVBA was used to provide an initial predicted assessment of the impact precipitation can have on ponding on level basins.

Three climatologically different locations were used to assess ponding on level basins in regions with differing rainfall amounts. They were Phoenix, AZ (precipitation 179 mm/yr and cotton), North Platte, NE (445 mm/yr and corn) and Columbia, MO (939 mm/yr and corn). Loamy sand (final infiltration rate 10.2 mm/h), loam (3.8 mm/h), and silty clay (1.3 mm/h) were considered at each site. Various irrigation strategies based on when to irrigate (amount depleted from root zone) and how much to irrigate (portion of root zone refilled relative to field capacity) were included along with a dryland strategy (no irrigation).

Ponding duration increased as rainfall increased when based on either monthly or maximum 24-h rainfall for the month. Similarly, irrigation influenced the maximum expected ponding time. In a humid region represented by Columbia, ponding times during the months irrigated did not exceed ponding time caused by rainfall (without irrigation) earlier in the growing season. For low infiltration rate soils at Columbia, the controlling condition would be during June when the rainfall is the highest. The longest ponding times at North Platte also occurred during the month of June, but were caused by both rainfall and irrigation. Deficit irrigation at North Platte resulted in shorter ponding times during the drier months, but such a strategy may not be attainable with level basins.

Ponding caused by rainfall on level basins, whether they are irrigated or not, was generally not excessive (10 h or less) even at Columbia, unless the basins were on soils with final infiltration rates of 2.5 mm/h or less. At Columbia for the loam soil, where a final infiltration rate of 3.8 mm/h was assumed, the expected ponding time every 10 years was only 4 h. At North Platte the corresponding ponding time was 3 h. A general concern with excessively long ponding times is commonly expressed by farm operators and is likely related to runoff water accumulating in low areas on non-level land. Level basins would alleviate this problem.

The simulation model and the resulting statistics, e.g., similar to some used in this text or for other time periods such as crop growth stage, potentially can be used as a guide in recommending the use of level basins in various climatic regions. The limitations on critical ponding time during the growing season dictate whether level basins could be used for a particular crop, on a certain soil, at the location in question. The use of level basins in any region also depends on the irrigation strategy employed, if any.

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